IX. BOTTOM SEDIMENT COMPOSITION

A. Introduction

Lake sediments have proven to be of extreme importance to limnologists because they play an important role in the determination of nutrient levels and productivity in the overlying waters.

A review of the factors that may affect sediment-water exchange reactions shows that insufficient information is available at the present time to predict the extent and, in many cases, the net direction of exchange for many compounds in most natural waters. Lake sediments contain significant concentrations of many metals and nutrients. The lake sediments act as a buffer system for these elements to control concentrations in the overlying waters. The effect of this buffer system could be to keep the concentrations in the overlying waters relatively constant even though the concentrations of the element in the inflowing waters vary greatly (Lee, 1970).

One of the most important reactions of this type is the exchange of phosphorus between a lake's sediments and the overlying waters as related to the eutrophication of the waters. Lee (1970) states that lake sediments typically contain one to two parts per thousand of phosphorus per kilogram of dry sediment.

Knowledge is particularly lacking on the role of lake sediments in maintaining phosphate levels in water. It is not known if the sediments of a lake act as a sink in which the majority of the phosphorus present is refractory, i.e., not available for exchange reactions.

Frink (1967) suggests that the center of a lake acts as a reservoir for both total and available nitrogen and phosphorus. He concludes that nutrients which accumulate in the bottom of a lake as eutrophication proceeds constitute a vast reservoir apparently capable of supporting plant growth in the event nutrient input is reduced. This was the case at Kezar Lake, North Sutton, New Hampshire. Even after phosphorus loading was dramatically reduced from a point source, phytoplankton blooms continued on an annual basis. Phosphorus-rich sediments continued releasing phosphorus into the upper water column supporting a vast population of phytoplankton (Connor and Smith, 1983).

In addition to phosphorus, metal concentrations in the sediment can play a role in the ecological health of a lake. With the increasing concern of acidic precipitation in New Hampshire, lake or pond pH and alkalinity have become increasingly important. Studies have shown various apparent mechanisms of response of the lake's biota to increased acidity, ranging from direct toxicity of hydrogen ion to disruptions of normal food-chain relations, behavioral patterns of animals, and biogeochemical cycles in the lake. Recent studies have shown increasing concentrations of heavy metal such as manganese, aluminum and zinc as a result of pH depressions below five units.

B. Chemical Characterization

A Wildco KB^{tm} coring device was utilized to extract an 11 inch sediment core. The core was collected at the deepest location of Mendums Pond and sectioned off into one inch upper, two inch middle and three to four inch bottom sediment column intervals. Metals were digested on a hot plate with 10 milliliters of ultra pure nitric acid and a final treatment with peroxide. Sediment phosphorus concentrations were determined colormetrically after nitric and sulfuric block digestion. Such measurements could reflect deposition rates, toxic metal concentrations, phosphorus sediment accumulation, and spatial variability over time. Comparison of other lake sediment core analyses performed in New Hampshire are presented in Table IX-1. A summary table of sediment analysis appears in Table IX-2.

Table IX-1
Comparison of Surface Sediments (first inch)
of some New Hampshire Lakes and Ponds.

Parameter/lake	Classification	Al	Cd	Cu	Fe	Pb	Mn	Zn	Tp
Mendums Pond Barrington	Oligotrophic	16,800	<4	<80	13,120	101	180	80	7,128
*Webster Lake Franklin	Mesotrophic	20,500	1	17	26,000	94	798	140	4,735
Mtn. Pond Chatham	Oligotrophic	25,120	<24	<80	16,320	98		184	4,530
Loon Lake Plymouth	Mesotrophic	14,921	<24	<80	30,595	48		159	7,211
Kezar Lake Sutton	Eutrophic	23,585	<236	830	16,038	58	283	6,604	5,569
French's Pond Henniker	Eutrophic	16,812	<30	69	27,525	723	832	317	10,165

All values in mg/kg dry weight of sediment
*Method utilizing CEM microwave (except Mn and Tp)

Table IX-2

Recoverable Metals From Mendums Pond Sediments

		Recoverable Metal Concentration (mg/kg)							
Sediment Section (inches)	Dry Wt (gms)	Al	Ca	Cu	Fe	Mn	Pb	Zn	P
0-1	0.100	15,600	2,700	13	4,000	180	55	200	7128
1-2	0.100	14,500	2,200	14	3,000	180	36	110	7777
2-3	0.100	18,500	2,000	20	4,000	150	117	140	5227
3-4	0.100	19,900	2,100	12	4,000	150	75	120	7008
4-5	0.101	10,990	1,980	11	3,960	139	41	129	5327
5-7	0.100	18,300	2,000	14	4,000	170	16	100	6826

Table IX-2

Recoverable Metals From Mendums Pond Sediments (continued)

		Recoverable Metal Concentration (mg/kg)							
Sediment Section (inches)	Dry Wt (gms)	Al	Ca	Cu	Fe	Mn	Pb	Zn	P
7-9	0.100	8,600	2,500	17	2,000	190	1	120	6471
9-11	0.100	6,000	2,900	12	1,000	200	4	120	6334

C. Sedimentation Rates and Sediment Age

The relative age of the sediments of Mendums Pond were estimated using lead concentrations as an indicator. Figure IX-4 depicts the increase in lead concentration at the 6 inch level. This increase corresponds to the introduction and increased use of leaded gasoline during the 1920's.

Utilizing this date and assuming the surface corresponds to 1987 when the core was removed, relative sedimentation rates can be estimated at .086 inches year^{-1} from the six inch to the surface layer.

These values correspond to values from other lakes that do not have point source discharges. The Connecticut Department of Environmental Protection estimated that 2.0 feet (0.61m) of sediment had been deposited in eutrophic Lake Lillionah between 1955 and 1980. This equals a sediment deposition rate of approximately 1 in. (2.5 cm) yr^{-1}. Sedimentation in Lake Lillionah is unusually high, as compared to most Connecticut lakes, in that Lillionah experiences dense summer blooms of blue-green algae and receives indirect discharge of treated wastewater from an upstream sewage treatment plant. Peterson et al (1973) discusses sedimentation rates for Lake Trummen, located in Sweden. Approximately 40 cm of FeS-colored (black) fine sediment was deposited over a period of 25 years, or at a rate of about 0.6 in. (1.6 cm) yr^{-1}. Lake Trummen was also subject to the discharge of wastewater effluent for many years, and the significance of internal nutrient recycling was well documented. At mesotrophic Stockbridge Bowl, located in Stockbridge, Massachusetts, Ludium (1975) reported a much lower sedimentation rate of 0.12 inches (3.0-3.2 mm) year^{-1}. The Maine Department of Environmental Protection assumes an approximate sedimentation rate of 0.08 inches (2.0 mm) year^{-1}.

D. Sediment Metals and Phosphorus

Values presented in the following discussion are for concentrations which were measured in the sediment and not in the water. Elevated metal concentrations would not be expected to be measured in lake water unless low pH values (below 5.0 units) were commonly measured within the lake.

1. Recoverable Aluminum

One of the most abundant elements on the face of the earth, aluminum occurs in many rocks but never as pure metal in nature. Although the metal itself is insoluble, many of its salts are readily soluble.

The toxicity of aluminum to the aquatic biota has been reviewed quite extensively with the recent association of resolublization of aluminum in acidic waters. Aluminum toxicity does not appear to be a significant problem, as long as pH is controlled and residual dissolved aluminum is not allowed to reach levels in the area of 50 ug Al/L. In areas where lakes have low ANC and acid rainfall is significant, lowering of lake pH could occur with a sudden increase in aluminum and probable toxic affects to the lake biota.

Aluminum concentrations in Mendums Pond (Table IX-3, Figure IX-1) sediments exibited a range of values. The maximum concentration observed was 19,900 mg/kg (3-4 inch segment), while the minimum was 6,000 mg/kg (9-11 inch segment). Aluminum concentrations observed in the upper seven inches of the sediment core were twice as high as concentrations in the lower four inches. Possible explanations of recent elevated aluminum concentrations include the leaching of parent bedrock from acidic precipitation and an increase of outboard motor use. Most of the current engine blocks are casted from aluminum. The wear and tear of these metal components produce tiny fragments which exit the motor into the water with the dispelled oil.

Aluminum concentrations analyzed at Mendums Pond fall into the low to mid range of sediment concentrations, compared to other analyzed sediment cores in New Hampshire (Table IX-2).

2. Recoverable Cadmium

In the elemental form, cadmium is insoluble in water. It occurs in nature largely as a sulfide salt. Cadmium is used in metallurgey to alloy with copper, lead, silver, aluminum and nickel. It is also used in electroplating, ceramics, photography and in insecticides. Cadmium concentrations measured in Mendums Pond were below the detection limts of other analyses conducted in other New Hampshire lakes for the method used (Table IX-1).

Table IX-3

Recoverable Aluminum

Mendums Pond, Barrington

Section (in)	Dry Weight (g)	mg/L	Volume (mL)	mg/kg
0-1	0.100	15.6	100	15,600
1-2	0.100	14.5		14,500
2-3	0.100	18.5		18,500
3-4	0.100	19.9		19,900
4-5	0.101	11.1		10,900
5-7	0.100	18.3		18,300
7-9	0.100	8.6		8,600
9-11	0.100	6.0		6,000
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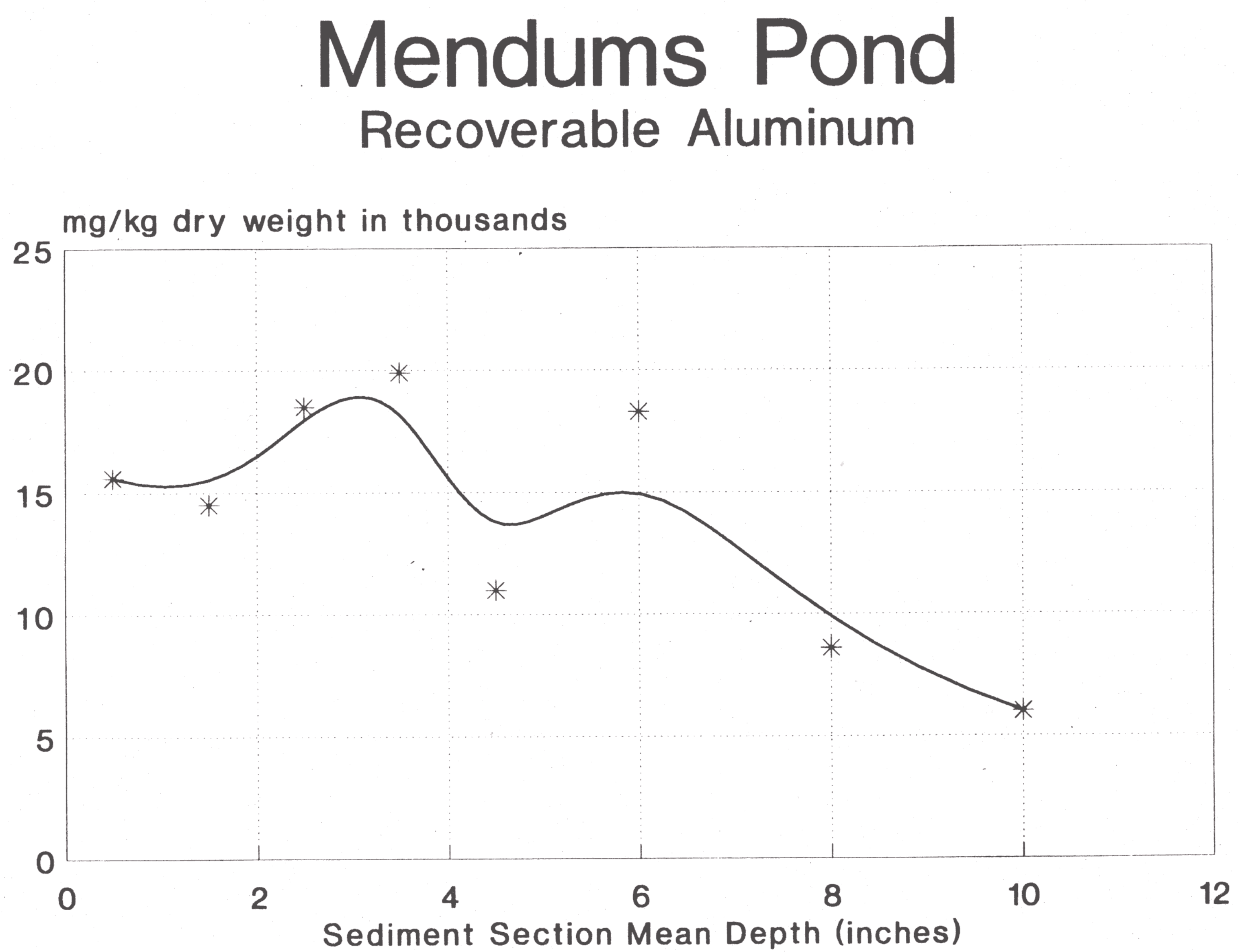

Figure IX-1: Recoverable Al in Sediments

3. Recoverable Copper

Copper salts occur in natural surface waters only in trace amounts, up to about 50 ug/L, and their presence is frequently due to the use of copper sulfate for the control of nuisance plankton species. Copper is used in many alloys, insecticides, fungicides, and wood preservatives.

Mendums Pond sediment copper concentrations ranged from a low of 10.9 mg/K in the 4"-5" layer to a maximum concentration of 20.0 mg/L in the 2"-3" layer. (Figure IX-2 and Table IX-4). Concentrations measured in all layers of Mendums Pond sediment were similar to other measured concentrations in New Hampshire (Table IX-1).

4. Recoverable Iron

Iron is the fourth most abundant, by weight, of the elements that make up the earth's crust. Common in many rocks, it is an important component of many soils, especially the clay soils.

Recoverable iron concentrations in Mendums Pond ranged from a minimum of 1,000 mg/kg in the 9-11 inch sediment layer to 4,000 mg/kg in the 0-7 inch section (Table IX-5). Iron concentrations were observed to be lowest in the deepest section of the sediment core and to progressively increase in concentration to the 0-1 inch layers (Figure IX-3). In comparison with other sediment studies conducted, Mendums Pond sediments contain moderate concentrations of recoverable iron (Table IX-1).

5. Recoverable Lead

Leaded gasoline, introduced in the 1920's, has been largely blamed for the increased levels of lead observed in the aquatic environment. The solubility of lead compounds in water depends heavily upon pH. Fish kept in water of pH 6.0 concentrate almost three times more lead than fish kept in water of pH 7.5. This is of startling significance for the northeast where lake waters are generally poorly buffered and acid precipitation is further decreasing the pH in many of our lakes and ponds.

Recoverable sediment lead concentrations (Table IX-6) ranged from below detectability (7-9 inches) to 117 mg/kg (2-3 inches). Lead concentrations were lowest in the bottom six inches of the Mendums Pond sediment core (Figure IX-4). Concentrations increased significantly from the 5 inch to the 2 inch section.

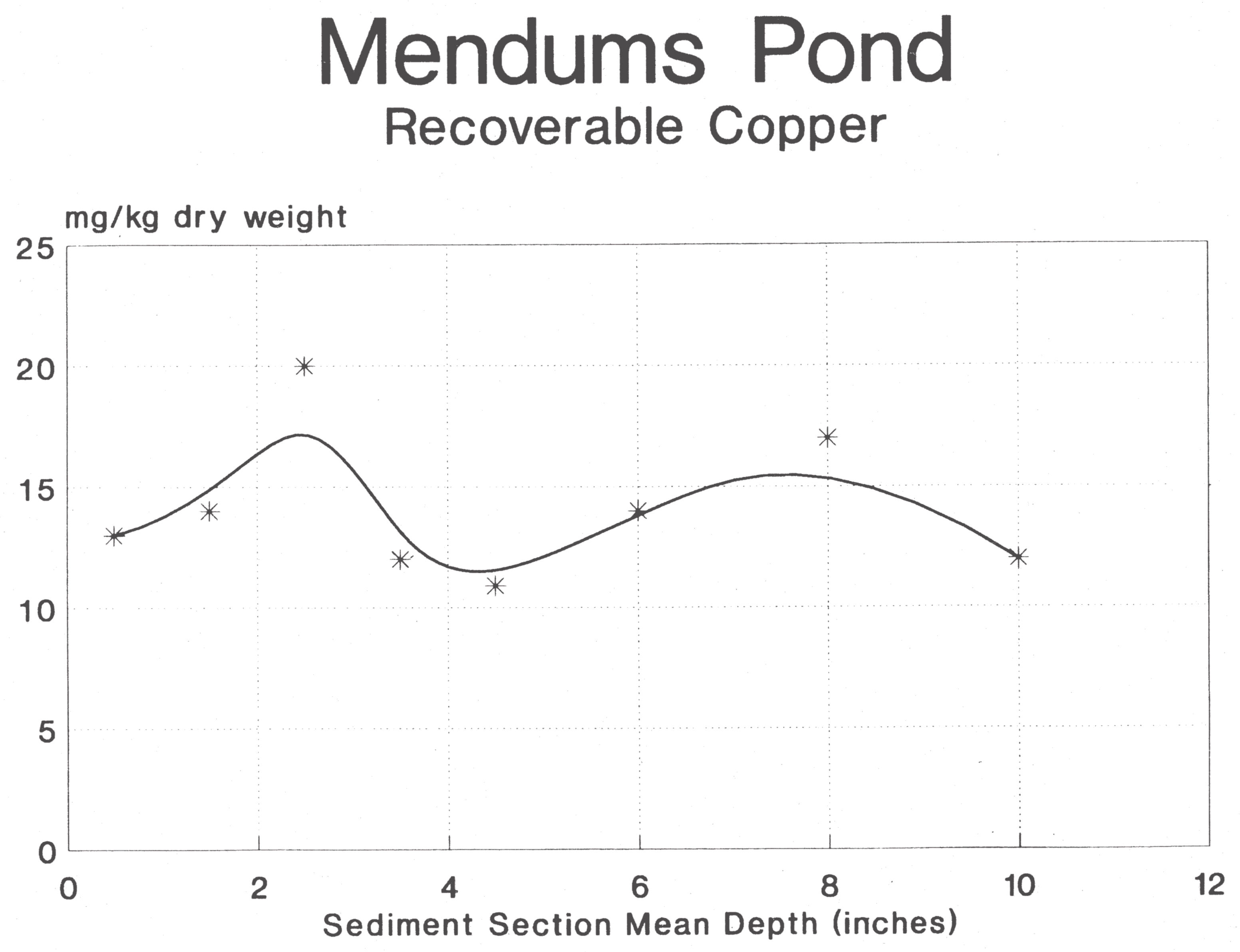

Figure IX-2: Recoverable Cu in Sediments

Table IX-4

Recoverable Copper

Mendums Pond, Barrington

Section (in)	Dry Weight (g)	mg/L	Volume (mL)	mg/kg
0-1	0.100	0.013	100	13.0
1-2	0.100	0.014		14.0
2-3	0.100	0.020		20.0
3-4	0.100	0.012		12.0
4-5	0.101	0.011		10.9
5-7	0.100	0.014		14.0
7-9	0.100	0.017		17.0
9-11	0.100	0.012		12.0
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Table IX-5

Recoverable Iron

Mendums Pond, Barrington

Section (in)	Dry Weight (g)	mg/L	Volume (mL)	mg/kg
0-1	0.100	4.0	100	4,000
1-2	0.100	3.0		3,000
2-3	0.100	4.0		4,000
3-4	0.100	4.0		4,000
4-5	0.101	4.0		3,960
5-7	0.100	4.0		4,000
7-9	0.100	2.0		2,000
9-11	0.100	1.0		1,000
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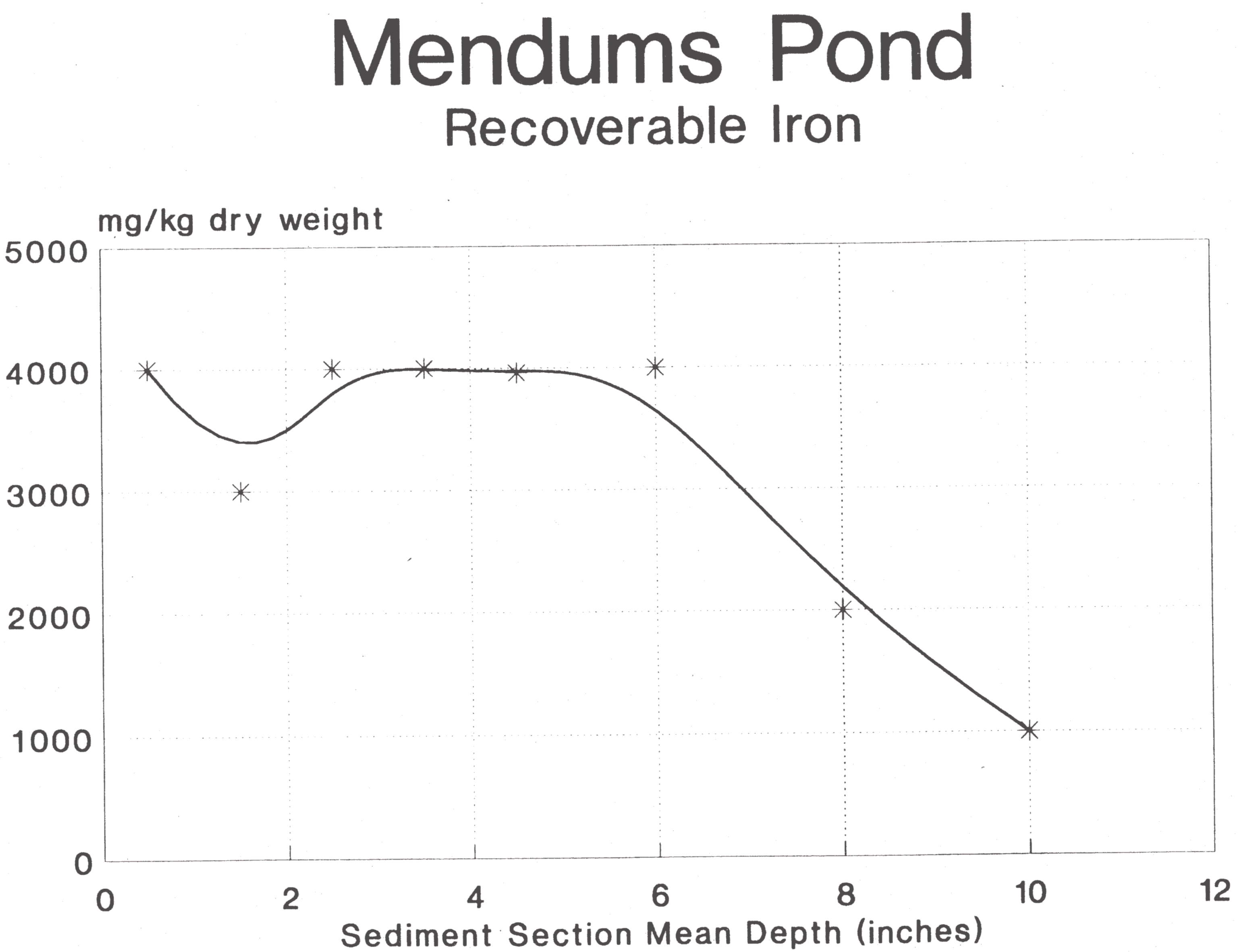

Figure IX-3: Recoverable Fe in Sediments

Table IX-6

Recoverable Lead

Mendums Pond, Barrington

Section (in)	Dry Weight (g)	mg/L	Volume (mL)	mg/kg
0-1	0.100	0.055	100	55.0
1-2	0.100	0.036		36.0
2-3	0.100	0.117		117.0
3-4	0.100	0.075		75.0
4-5	0.101	0.041		40.6
5-7	0.100	0.016		16.0
7-9	0.100	0.001		1.0
9-11	0.100	0.004		4.0
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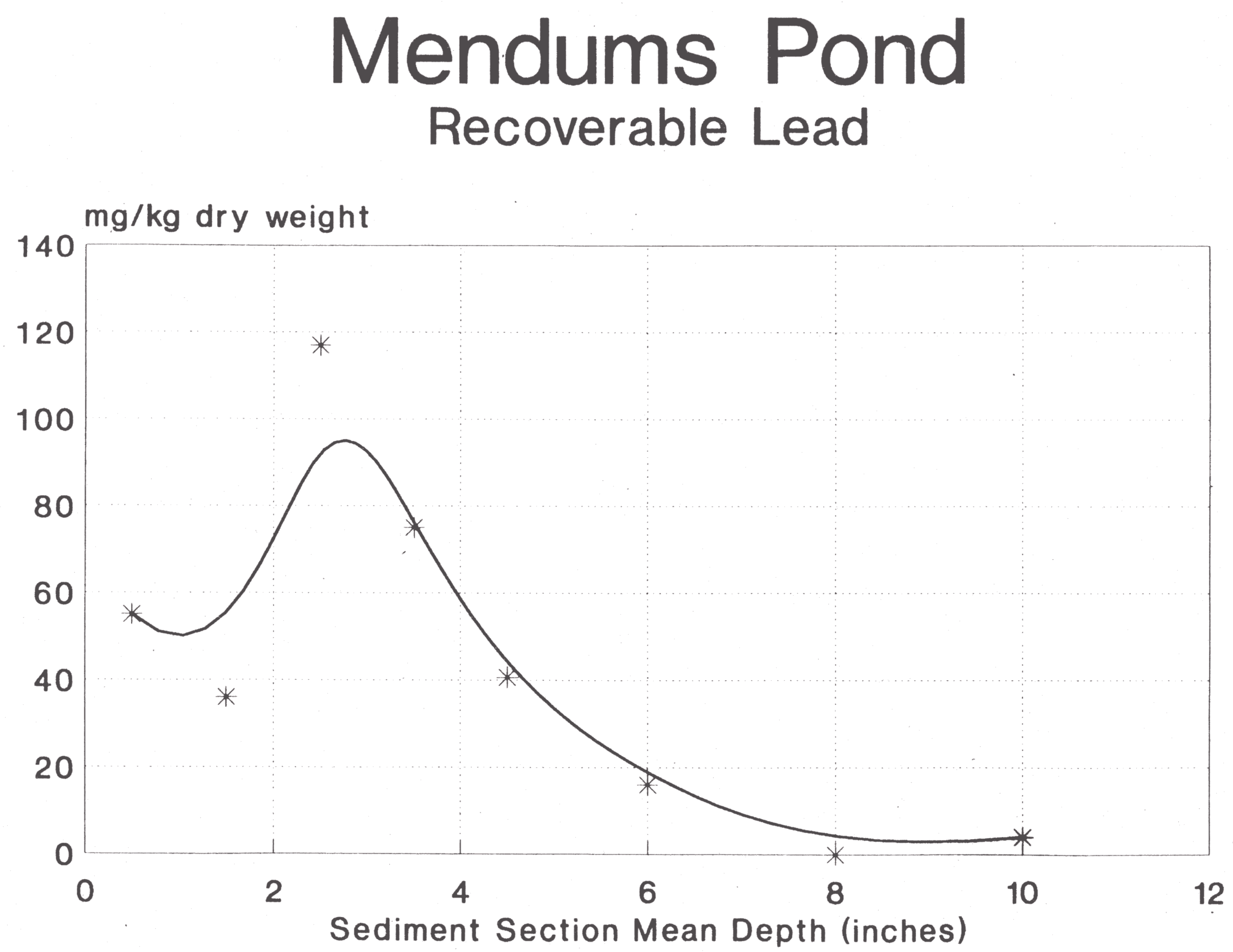

Figure IX-4: Recoverable Pb in Sediments

Lead concentrations in the top two inches decreased slightly. Sediment lead found in Mendums Pond is moderate when compared to other sediment studies conducted (Table IX-1).

6. Recoverable Manganese

Manganese is another common metal found in the earth's crust. Although not considered toxic, this metal, even in low concentrations, can cause aesthetic problems for water consumers. Manganese can cause abnormal taste, stain plumbing fixtures and clothes and deposits may accumulate in the plumbing system.

Manganese concentrations in Mendums Pond sediments ranged from 13.9 mg/kg in the 4-5 inch section to 200 mg/kg at the deepest section of the core (Table IX-7). Manganese concentrations varied with little depth (Figure IX-5). Manganese concentrations at the surface of Mendums Pond sediments were lower than the previously observed concentrations at other pond's in New Hampshire (Table IX-1).

7. Recoverable Zinc

Compounds of zinc with the common ligands of surface waters are soluble in neutral and acidic solutions, so that zinc is readily transported in most natural waters and is one of the most mobile of the heavy metals. Zinc is used for the anti-corrosive coating in galvanized metals and rubber products.

Most of the zinc introduced into the aquatic environment is partitioned into the sediments by sorption onto hydrous iron and manganese oxides, clay minerals, and organic materials. All zinc forms are potentially toxic if they can be sorbed or bound by biological tissue.

Zinc levels were relatively constant throughout the sediment core below 1 inch, ranging from 100 to 140 mg/Kg. The concentration increased significantly at the surface to 200 mg/Kg. (Figure IX-6 and Table IX-8) Comparisons of sediment zinc concentrations in other surveys reveal that Mendums Pond has lower concentrations in the upper sediment sections (Table IX-1).

Table IX-7
Recoverable Manganese
Mendums Pond, Barrington

Section (in)	Dry Weight (g)	mg/L	Volume (mL)	mg/kg
0-1	0.100	0.18	100	180
1-2	0.100	0.18		180
2-3	0.100	0.15		150
3-4	0.100	0.15		150
4-5	0.101	0.14		139
5-7	0.100	0.17		170
7-9	0.100	0.19		190
9-11	0.100	0.20		200
Blank	0.000	0.00		-----

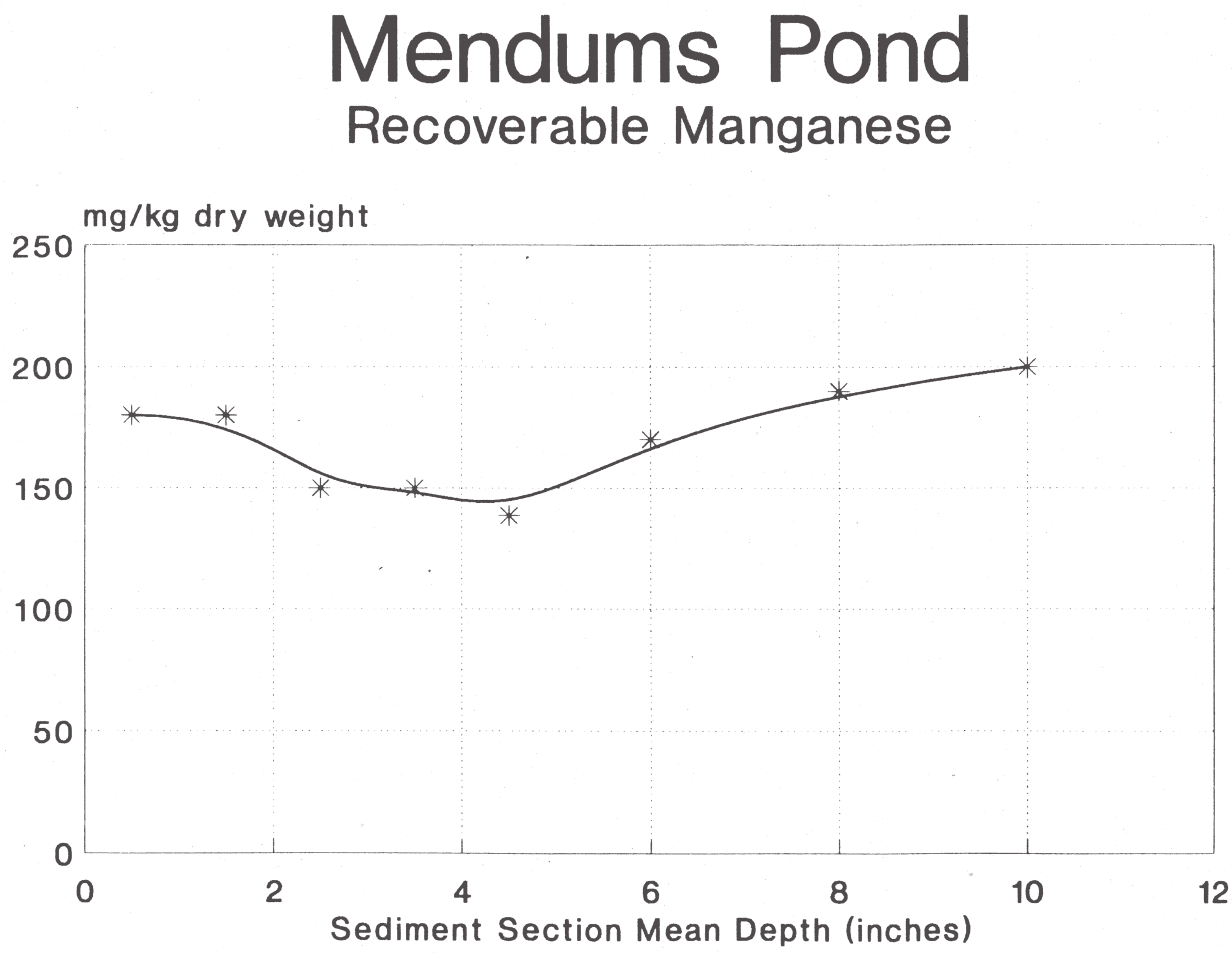

Figure IX-5: Recoverable Mn in Sediments

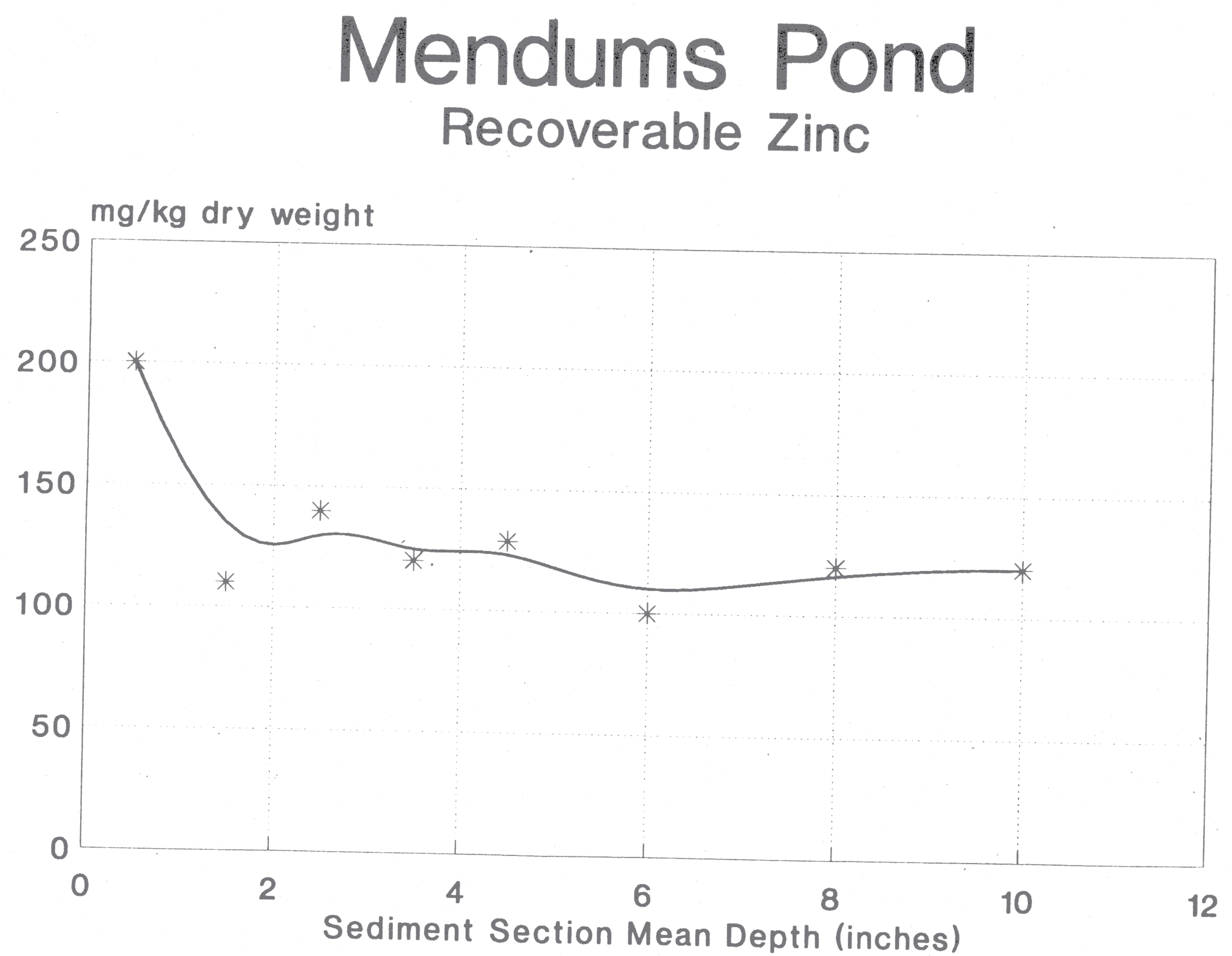

Figure IX-6: Recoverable Zn in Sediment

Table IX-8

Recoverable Zinc

Mendums Pond, Barrington

Section (in)	Dry Weight (g)	mg/L	Volume (mL)	mg/kg
0-1	0.100	0.20	100	200.0
1-2	0.100	0.11		110.0
2-3	0.100	0.14		140.0
3-4	0.100	0.12		120.0
4-5	0.101	0.13		128.7
5-7	0.100	0.10		100.0
7-9	0.100	0.12		120.0
9-11	0.100	0.12		120.0
Blank	0.000	0.07		-----

8. Recoverable Phosphorus

The measurement of phosphorus cocentration in a lake gives an indication of the extent of nutrient enrichment. The amount of phosphorus in New Hampshire lakes determines the level of plankton growth. Lake sediments often act as sinks and accumulate high concentrations of phosphorus over long periods of time. Phosphorus which has accumulated in the deep water sediments of a lake may be released into the water when the physical, biological and chemical conditions become conducive for its release. Usually, this release occurs during the summer months. If stratification is weak, this phosphorus migrates to the metalimnion to be utilized by the plankton community; otherwise, much of this hypolimnetic phosphorus is distributed to the entire water column during the fall overturn.

The identification of sediment phosphorus concentration is important to the phosphorus budget. Spatial distribution of sediment phosphorus with depth is important in the evaluation of lake restoration techniques and their feasibility. The uniform distribution of high concentrations of phosphorus throughout the sediment column would obviously make dredging an unfeasible restorative technique. However, sediment sealing with aluminum as a restorative technique might be a solution for this type of problem.

Most studies show that lake sediments typically contain 1000-2000 mg/kg of recoverable phosphorus. In twenty-seven borderline mesotrophic/eutrophic lakes located in Massachusetts, the mean concentration was 1,268 mg/kg, while concentrations of recoverable sediment phosphorus in 15 New Hampshire lakes ranged from 100 to almost 14,000 mg/kg. Sediment phosphorus concentrations in Lake Washington, Washington State (Edmondson, 1972), ranged from 1000 to 6000 mg/kg while the range in Lake Shagawa, Minnesota, was 1000-5000 mg/kg (Larson et al 1975).

Mean recoverable phosphorus in Mendums Pond (Table IX-9) ranged from 5227 mg/kg (2-3 inch layer) to 7777 mg/kg (1-2 inch layer). Sediment phosphorus concentrations did not exhibit any marked change through the depth of the core (Figure IX-7).

Moderate to high concentrations of sediment phosphorus were measured in Mendums Pond when compared to other sediment studies conducted in New Hampshire. The combination of hypolimnetic anoxia and high surface sediment phosphorus is chemically conducive to the release of phosphorus to the hypolimnion.

Table IX-9

Recoverable Phosphorus in Mendums Pond Sediments

Sediment Section (in)	Phosphorus Range (mg/kg) Min	Max	Phosphorus Mean (mg/kg)
0-1	6717	7540	7128.5
1-2	7653	7901	7777.0
2-3	4249	6205	5227.0
3-4	5998	8018	7008.0
4-5	4779	5875	5327.0
5-7	6009	7644	6826.5
7-9	5892	7050	6471.0
9-11	5883	6786	6334.5

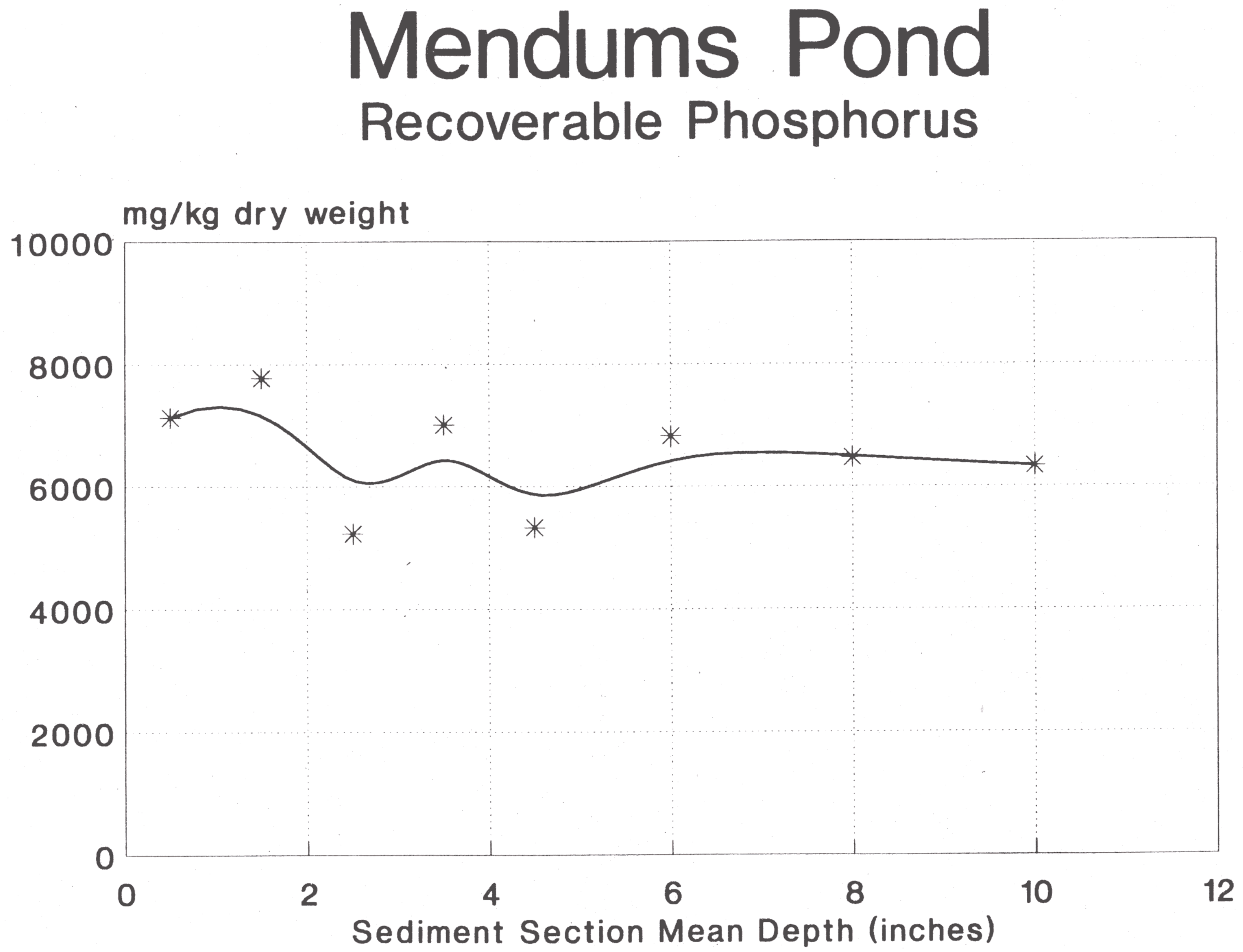

Figure IX-7: Recoverable P in Sediments

In lake mass balancing of phosphorus (Chapter VIII) revealed that sediment phosphorus uptake and release is probably occurring to a slight extent. As mentioned previously, it must be emphasized that these are simultaneously occurring functions in different sections of the lake, and other chemical, physical and biological activities are also occurring. While one section of the lake may be releasing phosphorus for part of the year, other sections are uptaking phosphorus. The data revealed that there is currently little problem with internal loading (Figure VIII-4).